Type Ia Supernovae are Excellent Standard Candles in the Near-Infrared
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Abstract
We use 89 Type Ia Supernovae (SN Ia) with optical and near-infrared (NIR) photometry to derive distances and create low redshift (z<0.04) Hubble diagrams. We explore both a Gaussian Process (GP) method and a mean Template method for fitting light curves (LCs) and we extract distances with a hierarchical Bayesian model that includes peculiar velocity and photometric uncertainties. For 56 SN Ia with both optical and NIR observations near max light, the GP method for the NIR LCs yields a Hubble-diagram intrinsic scatter of \( \sigma_{\text{int}} = 0.087 \pm 0.014 \) mag when referenced to NIR max and 0.090 +/- 0.014 mag, when referenced to B-max. For each NIR band, referencing to NIR versus B-Max yields smaller intrinsic scatter and weighted RMS. Using NIR LC templates referenced to B-Max yields a larger value of \( \sigma_{\text{int}} = 0.118 +/- 0.015 \) mag. Fitting the corresponding optical data using standard LC fitters that additionally use LC shape and color corrections, yields larger intrinsic scatter of \( \sigma_{\text{int}} = 0.148 +/- 0.022 \) with SALT2 and 0.128 +/- 0.018 with SNooPy. Applying our GP method to subsets of SN Ia NIR LCs at NIR max light, even without LC shape or host-galaxy dust reddening corrections, provides smaller intrinsic scatter in the inferred distances, at the ~2-3σ level, than standard optical methods that do correct for those effects.

Conclusions
NIR SN Ia LCs without LC shape or dust corrections are better standard candles than optical LCs with those corrections. NIR LCs at NIR max are as good or better as standard candles than when referenced to B-max. NIR data are also less sensitive to systematics from dust and intrinsic color variation. Our high-z RAISIN program on HST will exploit this promising infrared approach to limit systematic errors when measuring the expansion history of the universe and making inferences about dark energy (RAISIN: Tracers of cosmic expansion with SN Ia in the IR, PI: R. Kirshner, HST GO-13046, GO-14216). NIR SN Ia are thus very promising tools for next generation cosmology studies with HST, JWST, WFIRST.